NUMERICAL AND EXPERIMENTAL ANALYSES OF THE STRESS FIELD AHEAD OF FATIGUE CRACKS IN LASER-TREATED AA2198-T851

Introduction
Laser heating treatment (LHT) is a residual-stress-based approach exhibiting successful results in reducing fatigue crack propagation rates in laboratory specimens. Although its effect is usually related to the original residual stress field, it is known that cyclic loading and crack growth can cause relaxation and redistribution of residual stresses. In this work, M(T) specimens made of 0.2 mm thick AA2198-T851 alloy sheets with L-T and T-L crack orientations were treated with a fibre laser (power 200 W, displacement speed 1 mm/s) to produce two heating lines ahead of each crack front on one of each specimen’s face. Constant-amplitude loading tests were conducted on untreated and treated specimens at a zero-to-tension condition (R = 0). In addition, electrical resistance strain gauges bonded 4 mm away from the notch tip along the crack path were employed to measure the deformation behaviour ahead of the approaching crack tip. A numerical model was developed for the stress-strain state ahead of the crack, including plane stress condition, linear elastic response, the anisotropic Gurson-Tvergaard-Needleman (GTN) yield criterion coupled with damage, associative plastic flow rule and non-linear isotropic hardening Swift model. The mesh refinement was concentrated around the crack path direction from the notch tip until the specimen’s edge. The experimental results showed significant fatigue crack growth (FCG) retardation experienced by the laser-treated specimens; this effect was more pronounced in the L-T orientation. Numerical simulations could depict the field stress distribution in the treated specimens. Numerical simulations of damage increment under monotonic loading were adopted for a preliminary evaluation of the effect of LHT on the strain behaviour in the specimens.

Experimental Procedure

Table 1: Experimental procedure parameters and corresponding equipment detail.

The thermoviscoplastic GTN ductile damage model has been implemented in a computer code using 2D linear-order triangular finite elements. Half of the specimen has been discretised, resulting in a mesh with 440 nodes and 822 finite elements.

Figure 1: (a) Sketch of the investigated FAT/TG specimen with detail of the notch. Marked red are the laser heating lines; (b) Photography of FGT test with simultaneous strain gauge data acquisition.

Figure 2: discretisation adopted together with the temperature distribution. The peak at the graph correspond to the position of the laser lines (x=10 mm and y=14 mm).

Table 2: Material coefficients employed in the numerical simulations.

Conclusion

- Both AA2198-T851 LT and TL specimens with LHT exhibited an increase in lifespan greater than 300%, with the effect in the former crack orientation being more noticeable;
- da/dN x K curves indicate that LHT effect on FCG is more pronounced before the crack front achieves the first heating line, after this point, treated specimens follow the same trend as the AR ones;
- The numerical analysis points out that tensile residual stresses are present in the heating lines, but compressive ones are exhibited in the surroundings, with the latter greater on the notch tip (around 550 MPa);
- The numerical analysis on both the crack tip and 9 mm from the specimen’s edge is a first glance at how LHT specimens behave under submitted loading (monotonic loading in this case);
- Strain gauge data provided initial information regarding the redistribution of residual stresses, highlighting how the LHT causes the normal strain values to decrease for the same crack sizes, compared to the AR condition.

References